McGill AirFlow Corporation

An enterprise of United McGill Corporation—
Founded in 1951

One Mission Park
Groveport, Ohio 43125
614/836-9981, Fax: 614/836-9843
E-mail: mcgillairflow@compuserve.com
Web site: http://www.mcgillairflow.com

No. 159

**Type A DUCT-D-FUSER™ Grille
Performance and Design Methodology**

Engineering Report

Type A DUCT-D-FUSER™ Grille Performance and Design Methodology

There are many types of air diffusers available for commercial supply duct systems. Whether or not the duct system will be exposed is an important factor in the choice of air diffusers. Since exposed duct systems generally result in lower construction costs, there has been a surge in the use of exposed-type air diffusers. Among the common air diffusers used in exposed duct systems are the (1) tap-mounted rectangular grille/register, (2) radial diffuser, (3) flush-mounted grille, (4) slot diffuser, and (5) the McGill AirFlow Corporation's Type A DUCT-D-FUSER grille.

The Type A air diffusion grille has unique bell-mouth-like perforations that make up the outlet surface. The multitude of closely spaced perforations ensures a diffuse outlet pattern. See **Figure 1** for the Type A perforated screen detail. See **Figure 2** for a picture of a Type A grille.

The discharge pattern of a Type A grille is a function of the air velocity in the duct and the outlet static pressure: low velocities and high outlet static pressures promote radial flow, while fast velocities and low static pressures result in a more angular discharge pattern. See **Figures 3a** and **3b** for general trends.

The Type A grille's actual centerline velocity discharge angles range from 45° to 65°. **Figure 4** shows a graphical representation of the discharge angles. There is a slight spreading of the airflow around the centerline discharge angle. This degree of spreading is called the spread angle and is shown in **Figure 5**. **Table 1** shows the discharge and spread angle as a function of velocity in the duct and of outlet static pressure.

Figure 1
Type A air diffusion grille perforated screen detail (cross section)

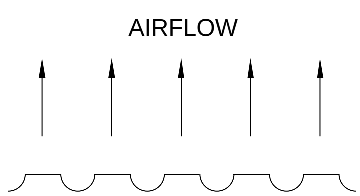

Figure 2
Type A air diffusion grille

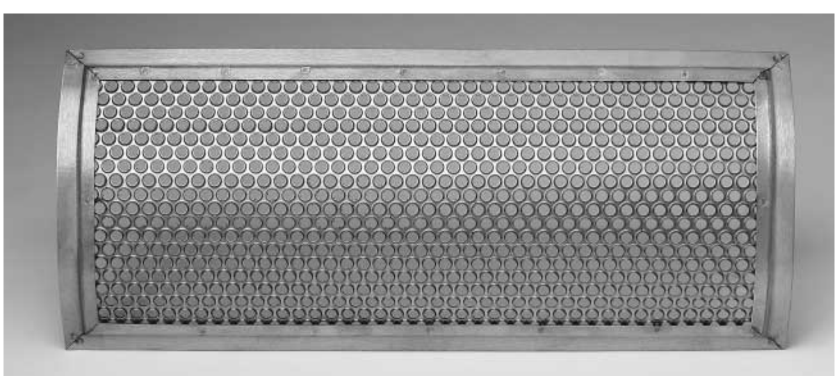

Table 1
Centerline velocity discharge and horizontal spread angles

Velocity in Duct (fpm)	Static Pressure (in wg)	Discharge Angle (degrees)	Spread Angle (degrees)
1000	0.05	59	8
1500	0.10	62	13
1500	0.18	65	16
2000	0.10	50	11
2000	0.25	60	13
2500	0.10	47	11
2500	0.25	54	13
2500	0.50	65	17
3000	0.10	45	12
3000	0.25	50	22
3000	0.50	68	19

Note: Data in **Table 1** acquired from 12-inch-diameter, 8-inch by 24-inch Type A air diffusion grille.

For applications requiring system flexibility, McGill AirFlow has developed the Type AD air diffusion fitting. This variable volume outlet is a Type A perforated screen mounted on a fitting body with a barrel damper mounted inside. See **Figures 6a** and **6b** for Type A and AD construction details. Performance of the Type AD fitting is the same as the Type A grille.

Type A DUCT-D-FUSER Grille Design Method:

McGill AirFlow has developed the following design method to properly size Type A grilles and Type AD fittings.

1. Sketch system layout, noting total volume flow rate (cfm) required for each duct run containing air diffusers. Divide the total length of a duct run by 6 to 12 feet to determine the number of air diffusers needed. Then divide the total cfm by the number of air diffusers to determine the cfm per air diffuser. A flow rate of up to 1000 cfm is acceptable for most applications, but flow rates from 1000 to 1500 cfm may be required for larger systems. Essentially, the same general rules that apply to rectangular tap-mounted grilles apply to Type A grilles and Type AD fittings. If the discharge angle is a critical item, refer to **Table 1** and space air diffusers accordingly.
2. Pick required outlet static pressure for desired throw distance from **Table 2**. Distances are measured along the centerline velocity.

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Figure 3a
Slow air velocity in duct and/or high outlet static pressure

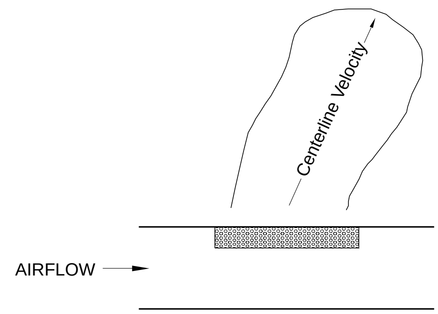


Figure 3b
High air velocity in duct and/or low outlet static pressure

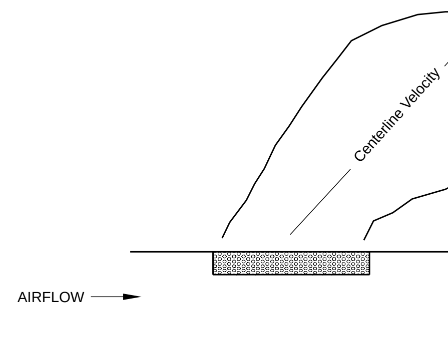


Figure 4
Centerline velocity discharge ranges (plan view)

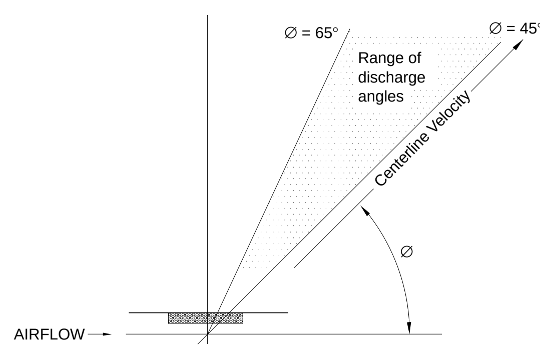


Figure 5
Horizontal spread (plan view)

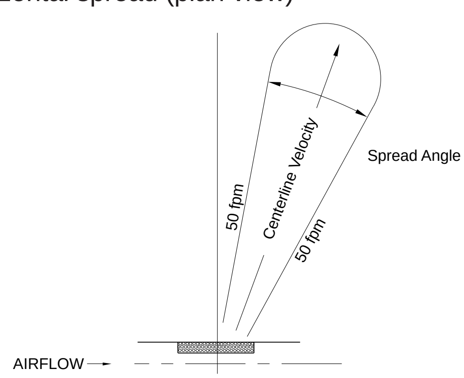


Table 2
Throw distance as a function of outlet static pressure

Outlet Static Pressure (in wg)	Maximum Throw for Terminal Velocity (V_t) (feet)	
	V_t = 150 fpm	V_t = 50 fpm
0.05	15	30
0.10	20	45
0.25	20	50
0.50	30	70

Note: Throw may actually be shorter than shown. High velocities in the duct (2500 to 3000 fpm) result in achieving the maximum throw distances shown.

3. Using McGill AirFlow's UNI-DUCT® duct design program (or other suitable program), enter the volume flow rate (cfm) and assign a required static pressure value chosen in **Table 2**, if throw velocity is not a critical item. If throw velocity is a critical item, subtract about 0.05 in wg from the outlet static pressure value chosen in **Table 2**. This is because the actual static pressure entering the air diffusion grille will increase after the duct system is sized. Use a take-off fitting number 51 (terminal outlet) for all air diffusers, except for those near end caps. Air diffusers near end caps have a take-off fitting number of 73 (capped tee).

   If designing projects that are acoustically sensitive and/or require radial flow, use maximum/minimum velocities of 1000/500 fpm. If designing for a typical commercial HVAC system (e.g., gymnasium, pool, office area) use maximum/minimum velocities of 1500 to 2500/800 fpm. If designing for lowest first cost and/or industrial environments where noise is not a concern, use maximum/minimum velocities of 3000/1200 fpm. Use the static pressure format in the UNI-DUCT program (see user's manual).

   You have the option to design a constant diameter system (pre-size sections), or let the UNI-DUCT program size the sections. Extended plenum designs look and perform the best, and will require you to enter (pre-size) the diameter of the trunk duct. Reference *Engineering Bulletin, Volume 2, Number 1, Extended Plenums* for additional information. Size the diameter for the best combination of acoustical and airflow performance, and the lowest first cost.
4. For each air diffuser, note the outlet entering static pressure from the UNI-DUCT program's output and look up the discharge cfm/ft^2 in **Table 3**. The UNI-DUCT program heading for entering static pressure is ENTG SP. This will be a starting point, an initial approximation of the actual discharge cfm/ft^2.
5. Divide the outlet cfm by the cfm/ft^2 found in **Table 3**; this equals the required surface

Figure 6a
Type A air diffusion grille mounted on spiral duct

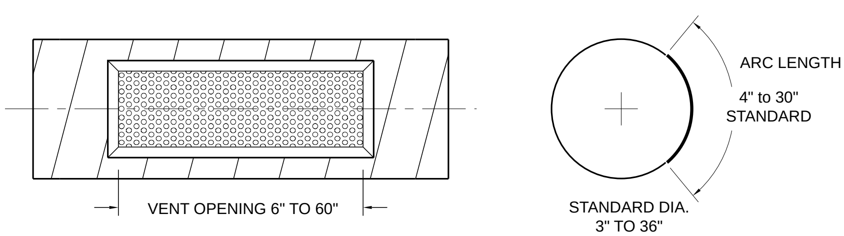


Figure 6b
Type AD air diffusion fitting

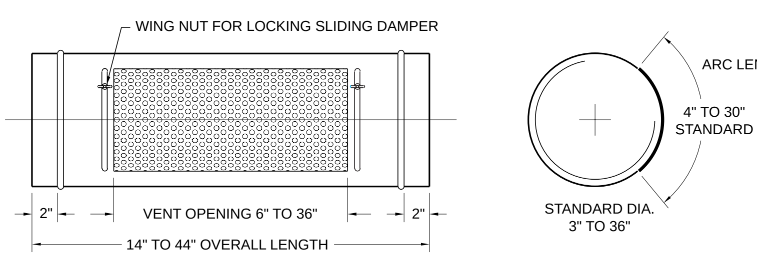


Table 3
Discharge cfm/ft^2 as a function of the UNI-DUCT program's entering static pressure of Type A air diffusion grille or Type AD air diffusion fitting

Entering Static Pressure from UNI-DUCT (in wg)	Discharge (cfm/ft^2)
0.01	140
0.05	350
0.10	500
0.20	720
0.30	890
0.40	1040
0.50	1160
0.60	1280
0.70	1380
0.80	1480
0.90	1570
1.00	1660

area (A_S), in square feet, of the Type A grille cut-out. See **Equation 1**.

Equation 1

$$A_s = \frac{\text{Outlet cfm}}{[\text{cfm/ft}^2 \text{ from Table 3}]} \ (\text{ft}^2)$$

6. Take the ratio of the Type A grille cut-out surface area (A_S) calculated in **Step 5** to the duct cross-sectional area (A_C). See **Equation 2**.

Equation 2

$$\text{Area Ratio} = \frac{A_s}{A_c} \qquad \text{where } A_c = \frac{\Pi D^2}{576}$$

7. Look up cfm/ft² in **Tables 4** through **7**. Use the area ratio calculated in **Step 6** to locate the correct table. Next, use the velocity in the duct and outlet entering static pressure to find the actual cfm/ft². Interpolation will most likely be required within a table and between tables. If the area ratio is less than 0.5, round it up to 0.5.

   Repeat **Steps 5** through **7** until a convergence on the actual discharge cfm/ft² is found.
8. Choose from one of the standard Type A grille arc lengths: 4, 6, 8, 12, 18, 24, or 30 inches.
9. Calculate the width of the cut-out based on duct diameter (D), area ratio (A_R), and arc length, using **Equation 3**.

   Note that there are 31 standard Type A grille sizes that include seven standard

Table 4

Discharge cfm/ft² as a function of entering static pressure and velocity in duct for $A_S/A_C = 0.5$

Outlet Static Pressure (in wg)	$A_S/A_C = 0.5$ Duct Velocity (fpm)						
	250	500	1000	1500	2000	2500	3000
0.01	190	180	160				
0.03	500	375	200	95			
0.05	570	440	245	155	135		
0.10	945	665	370	300	300	300	70
0.20	615	860	665	545	555	525	165
0.40			1065	940	750	810	610
0.50			1185	1105	865	920	750
0.75			1395	1435	1155	1145	1015
1.00			1550	1690	1520	1350	1230

Table 5

Discharge cfm/ft² as a function of entering static pressure and velocity in duct for $A_S/A_C = 1.0$

Outlet Static Pressure (in wg)	$A_S/A_C = 1.0$ Duct Velocity (fpm)						
	250	500	1000	1500	2000	2500	3000
0.01	225	155	25				
0.02	300	260	160	40			
0.03	385	330	240	75	140		
0.04	445	390	300	130	195		
0.05	475	435	350	190	245	125	
0.10	665	600	515	430	450	275	150
0.20			720	700	720	585	395
0.40			1000	1000	1055	1010	790
0.50				1115	1170	1150	960
0.75				1345	1390	1405	1320
1.00					1565	1595	1620

arc lengths (grille heights). See **Table 8** on page 6 for a list of the standard grille sizes.

Note that the required grille needs to be wider than the cut-out width that was calculated from **Equation 3**. For example, suppose the calculated cut-out width from **Equation 3** is 10.7 inches for a chosen arc length of 4 inches. So that the grille will completely cover the cut-out, a 4-inch by 12-inch Type A grille is used since it is wider than 10.7 inches. See **Figure 7** below. Sometimes you will choose an arc length that results in a calculated width (**Equation 3**) that is wider than the widest Type A grille for that arc length. In this instance you will have to choose a longer arc length and calculate a new width.

Equation 3

$$W = \frac{\Pi D^2(A_s/A_c)}{4(\text{Arc Length})} \text{ (inches)}$$

10. Determine discharge sound power levels for the resulting design. Each air diffuser will have its own sound power levels, so a calculation is done for each. Get the sound power level before adjustment from **Table 10**.

    A surface area adjustment factor (SAAF) is added to the sound power levels found in **Table 10**. **Equation 4** calculates the required surface area adjustment factor. This value is added to each octave band

Figure 7
Relationship between cut-out and actual Type A air diffusion grille

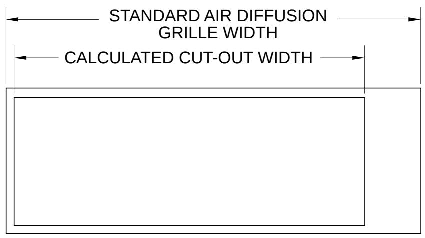


Table 6
Discharge cfm/ft² as a function of entering static pressure and velocity in duct for A_S/A_C = 2.0

Outlet Static Pressure (in wg)	A_s/A_c = 2.0 Duct Velocity (fpm)						
	250	500	1000	1500	2000	2500	3000
0.01		105	85	65			
0.05			425	325	300	255	170
0.10				630	605	530	505
0.15				710	740	770	790
0.20				790	830	860	875
0.25				840	900	965	990
0.50					1135	1250	1370
1.00					1285	1370	1620
1.00					1400	1440	1815

Table 7
Discharge cfm/ft² as a function of entering static pressure and velocity in duct for A_S/A_C = 3.0

Outlet Static Pressure (in wg)	A_s/A_c = 3.0 Duct Velocity (fpm)						
	250	500	1000	1500	2000	2500	3000
0.01		25	230	60			
0.03			335	350	205	40	
0.05				435	415	325	85
0.10					600	600	580
0.15							725
0.20							825
0.25							930

level for an individual air diffuser. Note that room effect must be taken into account to determine the resulting sound pressure levels in the occupied space. Refer to “Sound and Vibration Control” in the *ASHRAE Applications Handbook* for room effect determination. An alternate way of acquiring the surface area adjustment factor is to use **Table 9**.

Equation 4

$$SAAF = 10\text{Log}_{10} \frac{A_S}{1\ ft^2}$$

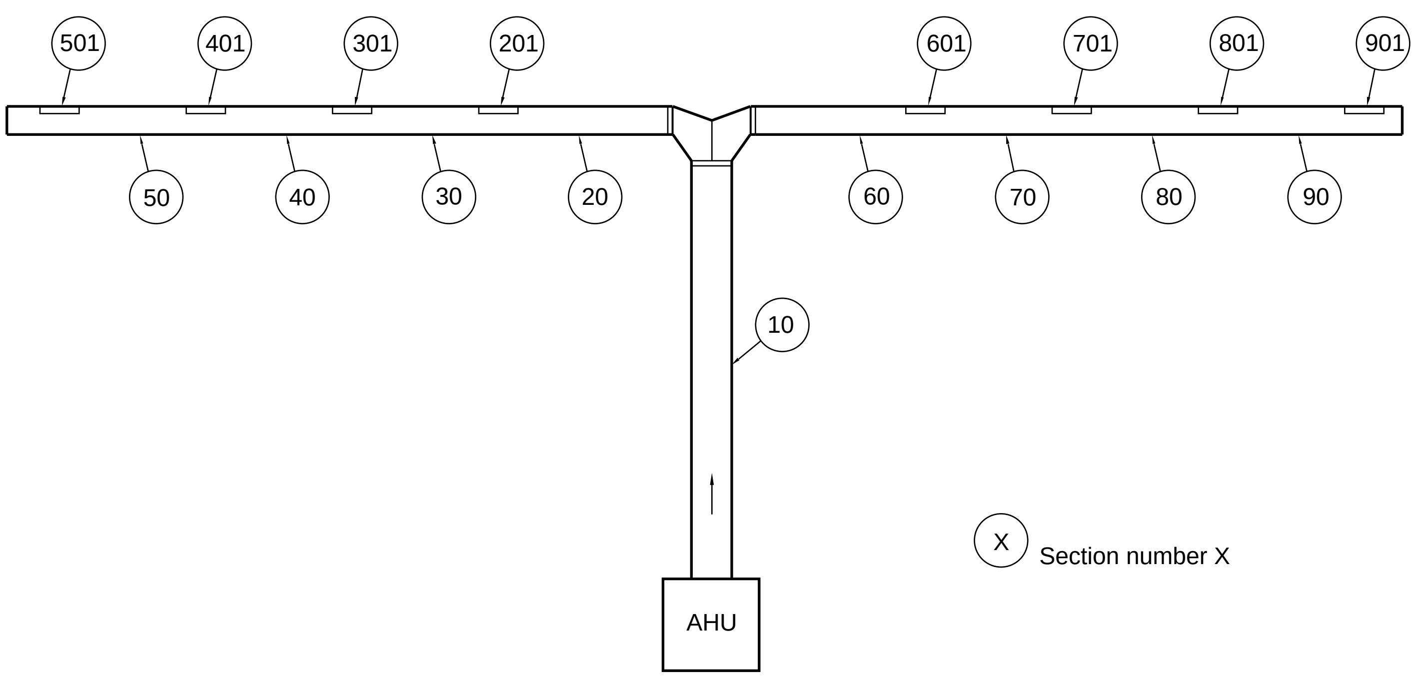
Table 8
Standard Type A air diffusion grille sizes

Arc Length or Grille Height (in)	Available Grille Sizes (in x in)
4	4 x 4, 4 x 6, 4 x 8, 4 x 10, 4 x 12
6	6 x 6, 6 x 10, 6 x 12, 6 x 16
8	8 x 8, 8 x 12, 8 x 16, 8 x 20, 8 x 24
12	12 x 12, 12 x 18, 12 x 24, 12 x 30, 12 x 36
18	18 x 18, 18 x 24, 18 x 30, 18 x 36, 18 x 54, 18 x 60
24	24 x 24, 24 x 36, 24 x 48, 24 x 60
30	30 x 48, 30 x 60

The following example illustrates the preceding steps.

1. A warehouse has been converted to an office building. The open-plan layout is shown in **Figure 8**. The duct system is about 25 feet above the finished floor. Since each typical branch is 40 feet long, four Type A grilles were spaced 10 feet apart. The volume flow rate per branch is 2860 cfm, so each air diffuser cfm is equal to 715 cfm. An RC level of 42 is desired at the terminal outlets to achieve RC 35 in the open office spaces.
2. Throw velocity is not critical, so an outlet static pressure required of 0.05 in wg will be used. If it is desired to completely minimize air disturbances, a static pressure required of 0.00 in wg should be used.
3. For a relatively quiet, radial flow, choose 1500/800 for maximum/minimum velocities to use in the UNI-DUCT program. An extended plenum design looks and performs the best. Therefore, we’ll use constant diameter. Let the UNI-DUCT program size the system for best balancing. Note that a VEE fitting is modeled as a bullhead tee with vanes. The program calculates both branch ducts at 22 inches. Now run the UNI-DUCT program again using the sizes from the VEE fitting (22-inch diameter) as the size of the two branch

Figure 8
Duct system layout



runs. Since the runs are typical you will have to run the UNI-DUCT program for only one branch. Presize all sections except for the air diffusers. The program calculates the entering static pressures for the air diffusers. Ignore the UNI-DUCT program's calculated outlet sizes. Data is summarized in **Table 11**.

Table 9
Surface area adjustment factor (SAAF)

Cut-out Surface Area, A_S (ft^2)	SAAF
0.25	-6
0.50	-3
0.75	-1
1.00	0
1.25	1
1.50	2
2.00	3
3.00	5

4. For the entering static pressure (ENTG SP) values, look up the discharge cfm/ft² in **Table 3**. Data is summarized in **Table 11**.
5. Calculate the cut-out surface area required for each air diffuser using **Equation 1**. Data is summarized in **Table 11**.
6. The cross-sectional area of the duct the Type A grille is attached to is equal to:

$$A_C = \frac{\Pi D^2}{576} = \frac{\Pi (22)^2}{576} = 2.64 \text{ ft}^2$$

The area ratio for each air diffuser cut-out is calculated and summarized in **Table 11**.

7. Find the actual cfm/ft² from interpolation between 0.5 and 1.0. This first iteration is summarized in **Table 11**. Repeat **Steps 5** through **7**. Continue this process until you converge on the actual discharge cfm/ft². The results of the iterations for this example are shown in **Table 12**.

Table 10
Airflow generated sound power level per 1 ft² Type A air diffusion grille surface area

cfm/ft² from Step 7	Center Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
100	41	42	35	35	31	24	10	0
300	42	44	37	38	34	29	17	8
500	44	46	40	42	38	34	24	16
700	46	48	43	45	42	39	31	25
900	47	50	45	48	45	44	38	33
1100	49	52	48	51	49	49	45	41
1300	50	54	50	54	52	54	52	50
1500	52	56	53	58	56	59	59	58

Table 11
Summarized information for **Steps 3-7**

Section	Step 3: Velocity in Duct (fpm)	Step 3: Volume Flow Rate (cfm)	Step 3: Entering Static Pressure (in wg)	Step 4: Discharge from Table 3 (cfm/ft²)	Step 5: Cut-out Surface Area Required, A_s (ft²)	Step 6: Area Ratio per Step 6 (A_s/2.64)	Step 7: 1st Iteration of Actual Discharge (cfm/ft²)
201	1085	715	0.07	410	1.74	0.66	317
301	814	715	0.08	440	1.63	0.62	431
401	542	715	0.10	500	1.43	0.54	636
501	271	715	0.11	522	1.37	0.52	682
601	1085	715	0.07	410	1.74	0.66	317
701	814	715	0.08	440	1.63	0.62	431
801	542	715	0.10	500	1.43	0.54	636
901	271	715	0.11	522	1.37	0.52	682

8. Pick an air diffusion grille height or arc length of 12 inches.
9. Size each air diffuser cut-out using **Equation 3**, and pick an appropriate air diffusion grille from **Table 8** to cover the cut-out. Results are summarized in **Table 13**.
10. Determine discharge sound power levels. First, determine the discharge sound power level per unit area using the results from **Table 10**. Results are summarized in **Table 14**. Next, calculate surface area adjustment factor (SAAF) for each air diffuser using **Equation 4** or **Table 9**. Results are summarized in **Table 16**. The SAAF for each section (**Table 16**) is added to the sound power level per unit area value (**Table 14**) for each octave band. For example, add 3 to each sound power level per unit area for section 201.

    You now have the resulting sound power level for each air diffuser. See the discharge sound power levels for each air diffuser in **Table 15**.

You're finished. All air diffusers have been sized and the relative airflow and acoustical performance has been quantified. Notice that for the worst case, the system is close to meeting RC 42 at the outlets (RC 35 in occupied space). Refer to *Acoustical Engineering Report Number 6, Applying Acoustics—Part 3*, for options to more closely meet acoustic requirements.

To make sure your engineered Type A air diffusion grille or Type AD air diffusion fitting is constructed properly, use the following specifications.

Table 12
Iteration of actual discharge (cfm/ft^2)

Section	1st Iteration of Actual Discharge (cfm/ft^2)	2nd Iteration of Actual Discharge (cfm/ft^2)	3rd Iteration of Actual Discharge (cfm/ft^2)	4th Iteration of Actual Discharge (cfm/ft^2)	5th Iteration of Actual Discharge (cfm/ft^2)	6th Iteration of Actual Discharge (cfm/ft^2)	7th Iteration of Actual Discharge (cfm/ft^2)	Final Area Ratio (A_s/A_c)
201	317	362	338	349	344	346	346	0.79
301	431	432	432					0.63
401	636	640	640					0.50
501	682	685	685					0.50
601	317	362	338	349	344	346	346	0.79
701	431	432	432					0.63
801	636	640	640					0.50
901	682	685	685					0.50

Note: If area ratio was less than 0.50, it has been set equal to 0.50.

Table 13
Summary of **Steps 8** and **9**

Section	Area Ratio per Step 6	Cut-out Dimensions		Air Diffusion Grille Dimensions	
		Step 8: Chosen Arc Length[1] (in)	Step 9: Diffuser Width per Equation 3 (in)	Needed Grille Size to Cover Cut-Out	Grille Size for Uniform Look
201	0.79	12	25	12 x 30	12 x 30
301	0.63	12	20	12 x 24	12 x 30
401	0.50	12	16	12 x 18	12 x 30
501	0.50	12	16	12 x 18	12 x 30
601	0.79	12	25	12 x 30	12 x 30
701	0.63	12	20	12 x 24	12 x 30
801	0.50	12	16	12 x 18	12 x 30
901	0.50	12	16	12 x 18	12 x 30

[1] If 8 inches had been chosen, the required width per **Equation 3** would have yielded a length wider than the widest air diffusion grille (8 x 24). Therefore, a 12-inch arc length was chosen.

Table 14
Sound power level per unit area (dB/ft^2)

Section	Discharge (cfm/ft^2)	Sound Power Level per Unit Area (dB/ft^2)							
		Center Frequency (H_z)							
		63	125	250	500	1000	2000	4000	8000
201	345	42	44	37	38	34	30	19	10
301	432	43	45	39	41	37	33	22	14
401	640	45	47	42	44	41	38	29	22
501	685	46	48	43	45	42	39	31	24
601	345	42	44	37	38	34	30	19	10
701	432	43	45	39	41	37	33	22	14
801	640	45	47	42	44	41	38	29	22
901	685	46	48	43	45	42	39	31	24

Table 15
Discharge sound power levels (dB)

Section	Discharge (cfm/ft^2)	Discharge Sound Power Levels (dB)							
		Center Frequency (H_z)							
		63	125	250	500	1000	2000	4000	8000
201	345	45	47	40	41	37	33	22	13
301	432	45	47	41	43	39	35	24	16
401	640	45	47	42	44	41	38	29	22
501	685	46	48	43	45	42	39	31	24
601	345	45	47	40	41	37	33	22	13
701	432	45	47	41	43	39	35	24	16
801	640	45	47	42	44	41	38	29	22
901	685	46	48	43	45	42	39	31	24

Table 16
Summary of surface area adjustment factor (SAAF)

Section	Discharge (cfm/ft^2)	Cut-out Surface Area Required, A_s (ft^2)	SAAF (Equation 4)
201	345	2.07	3
301	432	1.66	2
401	640	1.12	0
501	685	1.04	0
601	345	2.07	3
701	432	1.66	2
801	640	1.12	0
901	685	1.04	0

Type A DUCT-D-FUSER Grille or Type AD DUCT-D-FUSER Fitting Specifications

Custom air diffusion devices shall be provided where indicated on the drawings. Material shall be carbon steel. Air diffusers shall be designed to provide the required cfm and terminal velocity for the available pressure noted in the drawing schedule. Submittals shall include calculations or design program printouts noting the air diffuser size, spacing, and arc length. Throw distance and the approximate pressure drop shall be noted. Air diffusers shall be constructed of nozzled, perforated panels flush-mounted to spiral duct (or fitting bodies). Solid barrel dampers shall be supplied where specified to provide system balancing.

Acceptable Product: McGill AirFlow Corporation Type A DUCT-D-FUSER Grille, or Type AD DUCT-D-FUSER Fitting.

McGill AirFlow Corporation

An enterprise of United McGill Corporation—Founded in 1951

Form No.: SMD ER#159 3/00